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A REVIEW OF GAME THEORETIC AND SOCIAL PSYCHOLOGICAL MODELS OF COALITION FORMATION

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**College of Commerce and Business Administration
University of Illinois at Urbana-Champaign**



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OF COALITION FORMATION

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A Review of Game Theoretic
and Social Psychological Models
of Coalition Formation

Abstract

This paper reviews three classes of game theoretic solution concepts (solutions, subsolutions, and the core, bargaining set models, and the Shapley value) and four social psychological models (Minimum Resource theory, Minimum Power theory, Bargaining theory, and the Weighted Probability model) of coalition formation. The research that has been conducted on characteristic function games and on coalition situations involving more than three players has been summarized and the models have been evaluated. The advantages of collaboration between the two disparate but similar areas are discussed.

Formal theory concerning coalition behavior has been studied by game theorists since 1944 (von Neumann and Morgenstern) and by social psychologists since 1956 (Caplow). The two areas have adopted different philosophical approaches and have made limited progress in their relatively independent pursuits of knowledge. Game theorists have developed elaborate and elegant mathematics (i.e., normative theory) but have paid little attention to the applicability of their results to human behavior. Social psychologists, on the other hand, have collected a large amount of data on three-person groups, but have only recently expanded their descriptive models in attempts to predict bargaining behavior in larger, more complicated conflict situations. This paper summarizes selected portions of the research and theory from the two areas and attempts to locate the common ground between them. A concerted effort bridging the two areas holds increased promise for breakthroughs which each field alone might find unattainable.

This paper limits its review to aspects of the two areas that are most similar and that, therefore, have the greatest collaborative potential. Extensive reviews of the game theory literature can be found in Luce and Raiffa (1957) or Rapoport (1970). Reviews of earlier social psychological research can be found in Chertkoff (1970) or Stryker (1972). Present coverage of game theoretic models is restricted to characteristic function models of cooperative games; coverage of social psychological models is restricted to those which make a priori predictions for either the formation of or the payoffs to certain coalitions. These restrictions preclude, for instance, discussion of the Nash equilibrium (1951) and Laing and Morrison's (1973) model of sequential games.

Game Theoretic Models

A major distinction in the study of n-person games is made between cooperative and non-cooperative games. Cooperative games are those in which the players have the opportunity to communicate with one another and to form binding agreements. Non-cooperative games do not permit binding agreements, and may even forbid communications. Thus, for example, the usual form of the prisoner's dilemma game is non-cooperative. (Cooperative games, on the other hand, are those where the players bargain to determine their pay offs.)

In describing cooperative games, most theoretic models utilize the characteristic function. The characteristic function of a game specifies a value or payoff to each possible coalition, including one-person coalitions. For instance, a three-person game with outcomes of 1 for each two- and three-person coalition and 0 for all one-person coalitions would have the following characteristic function:

$$v(A) = v(B) = v(C) = 0; \quad v(AB) = v(AC) = v(BC) = v(ABC) = 1$$

where $v()$ indicates the value or payoff to a coalition, and A, B, and C are actors or parties in the game.

The characteristic function, then, emphasizes the payoffs that coalitions receive: coalitions are differentiated on the basis of the payoffs they can obtain.

Solutions and Subsolutions

von Neumann and Morgenstern's (1944) presentation of n-person conflict situations led them to the question of what outcomes might be considered stable. They introduced the notions of imputations

and domination. An imputation is a payoff configuration that satisfies conditions of individual rationality (i.e., a party will not accept a payoff from a coalition that is less than the payoff it can receive playing alone) and Pareto optimality (i.e., a payoff will not be considered if another payoff increases the outcomes of at least one of the included parties while not reducing the payoffs of any of the other included parties). Domination refers to a relationship between potential imputations: For a game with characteristic function \underline{v} , an imputation $\underline{y} = (y_1, \dots, y_n)$, that specifies a payoff for each of the n players, dominates an imputation $\underline{x} = (x_1, x_2, \dots, x_n)$ with respect to a non-empty coalition Q when the following conditions are met:

- (1) $\underline{v}(Q) \geq \sum_{i \in Q} y_i$
- (2) $y_i > x_i$ for every i in Q .

An example of a set of imputations from the game mentioned earlier would be

$$(\frac{1}{2}, \frac{1}{2}, 0), (\frac{1}{2}, 0, \frac{1}{2}), (0, \frac{1}{2}, \frac{1}{2})$$

where the imputations refer to payoffs to (A, B, C) when the AB coalition has formed, the AC coalition has formed, and the BC coalition has formed, respectively. An alternative imputation, $(\frac{3}{4}, 0, \frac{1}{4})$, dominates the first member of the above set of imputations. In other words, players A and C receive greater payoffs in this second imputation than they did in the first, and they have the power to enforce the new imputation if they wish. Notice also that the third imputation in the above set dominates this alternative imputation. A series of imputations, where one imputation succeeds and dominates the previous imputation, could result in an endless string of dominations. However, von Neumann and Morgenstern noted that certain sets of imputations do promote at least a fragile form of stability. (For instance, consider the situation where you are player A and player C offers

you $3/4$. If you realize that player B can then retaliate with the third imputation in the above set, you may be content to stay at a point where you receive $1/2$.) They worked from two assumptions: any solution set should contain imputations that (a) do not dominate each other, and (b) dominate any imputation outside the set. The example above, where the set of imputations gives a payoff of $1/2$ to each member of a coalition but does not specify which coalition will form, satisfied both assumptions. Thus it is a von Neumann-Morgenstern solution set. It is not, however, the only solution set for this game. For most n-person games, there are large numbers of solution sets. In addition, as with other game theoretic models, not only are the outcomes for particular coalitions non-unique, there is also little attempt to determine which coalition(s) might form most frequently.

An additional problem with von Neumann and Morgenstern's concept of solution sets is the fact that they do not exist for every n-person characteristic function game. Lucas (1968) has found an example of a ten-person game that does not have a solution.

Recently Roth (1976) has reported a modification of the concept of solutions, called subsolutions. The concept of subsolutions relaxes the condition that states that any imputation outside the solution set is dominated by a member in the set to state that any imputation outside the set of subsolutions that dominates a member of the set is in turn dominated by another member of the set. In this way, only imputations that "threaten" members of the set need to be dominated by another member of the set. This modification removes the problem of the general existence of solution sets, but does not change the non-uniqueness of the solution or the indeterminacy of particular coalitions.

There is another solution concept that has the advantage of yielding fewer predictions for games where it is not empty. The core consists of the imputations in a game that are undominated. For instance, in a game with this characteristic function:

$$v(A) = v(B) = v(C) = v(BC) = 0; v(AB) = v(AC) = v(ABC) = 1,$$

(where player A is essentially a monopolist) the core consists of a single payoff configuration, $(1, 0, 0)$, where the monopolist obtains the entire payoff. Any other payoff configuration is dominated by the core. For this example, the core is an extreme point; in other games, it may not be so extreme. The core is a compelling solution for game theorists, and is one that is a subset of most of the game theoretic solution concepts (including solutions and subsolutions). The core of a game, however, may not exist.

Bargaining Set Models

Another approach to n-person characteristic function games is that of the bargaining set (Aumann and Maschler, 1964). As with solutions, the bargaining set assumes individual rationality; it does not, however, assume Pareto optimality. Rather, the bargaining set is based on the concepts of objections and counter-objections. The bargaining set resembles the core (which it contains) and is always non-empty. The use of an example makes an explanation of the theory much easier. Consider the following characteristic function game:

$$v(i) = 0; v(AB) = 70; v(AC) = 60; v(BC) = 50; v(ABC) = 75,$$

where i refers to individual players, A, B, and C. Suppose that players A and C are negotiating to divide the 60 points which they can obtain, with A proposing that he receive 45 points, and C 15 points. Player C can raise an objection to A by saying that he can form a coalition with player B,

giving Player B 20 points (which is more than he would receive if A and C formed a coalition), and obtaining 30 points for himself. Given this objection, however, A can raise a counter-objection, saying that he can retain his original 45 points in a coalition with B, and give B 25 points (which is more than C is offering him in his objection).

In this example, one member of a potential coalition may attempt to increase his payoffs by using his alternative coalitions as a threat. In general, an objection of player i against player j proposes an alternative coalition Q, such that i is included in Q, j is excluded from Q, and the members of coalition Q receive larger payoffs than they did previously. A counter-objection also proposes an alternative coalition, say R, where player j obtains at least as much as he did in the original coalition with player i, and where other members of R do at least as well or better than they did in Q. The bargaining set, then, consists of those payoff configurations where a valid counter-objection can be raised for any possible objection. Thus, a fragile state of stability, similar in nature to the solution concept of von Neumann and Morgenstern, is proposed.

For the last characteristic function game mentioned above, the bargaining set contains the following payoff configurations:

$$(40, 30, 0), (40, 0, 20), (0, 30, 20)$$

(It also contains elements for the grand coalition; however, different forms of the bargaining set specify different outcomes for the grand coalition.) Several relationships among the members of the bargaining set are interesting to note. In this example, as in other examples where $\underline{v}(i) = 0$, $\underline{v}(ABC) \leq \frac{\underline{v}(ij)}{2}$, and $\underline{v}(ij) = \text{some positive integer}$, the payoff configurations in the bargaining set, regardless of the final coalition structure, specify

constant payoffs to the players when they are included in the winning coalition. Such games are called quota games, because quotas, ω_i , can be assigned to each player such that:

$$v(ij) = \omega_i + \omega_j, \text{ where } i, j = A, B, C, \text{ and } i \neq j.$$

For quota games, the bargaining set predicts that each player should receive his quota. However, as with the other models that have been discussed, the bargaining set does not specify which of the possible coalitions might form most frequently. For games that are more complicated than quota games, the bargaining set does not predict a specific payoff for each of the included players, but, rather, predicts a range of outcomes for each player. For instance, consider the following characteristic function:

$$v(i) = v(BC) = v(BD) = 0; v(Aj) = v(Ajk) = v(BCD) = 72,$$

where i = any player, (A, B, C, or D), and j and k = any player except A.

In this game, (called an Apex game), player A is denoted the Apex player because he needs only one partner to form a winning coalition and can only be excluded by a coalition of all the other players. The bargaining set includes payoff configurations for the two person coalitions such that $36 \leq x_A \leq 54$ and $18 \leq x_j \leq 36$, where x_A refers to the Apex player's payoff and x_j refers to the payoff of A's coalition partner.

Two additional models, both of which are related to the bargaining set, have been proposed in order to make more specific predictions for most games. The kernel (Davis and Maschler, 1965) for the game above specifies equal outcomes for player A and his partner. The rationale for this outcome is that when two or more potential coalition members trade objections and counter-objections, one player may, in a sense, "outweigh" another if the excess payoff he can receive from an alternative coalition exceeds the excess payoff his potential coalition partner can receive in the alternative coalition he proposes. Thus, an equilibrium state may occur when neither

player "outweighs" the other, i.e., when the excess each can obtain from alternative coalitions is equal. For three-person quota games, the kernel and the bargaining set are identical. For more complicated games, the kernel is included in the bargaining set and is the "equality" endpoint of the range of payoff configurations in the bargaining set, i.e., $X_A=36$, $X_J=36$, above.

Another variation of the bargaining set, the competitive bargaining set (Horowitz, 1972), predicts the opposite endpoint of the bargaining set's range of predictions. The competitive bargaining set assumes that players not included in the originally considered coalition will not sit by passively, waiting for one member of this coalition to make an objection, but will make proposals themselves. Thus, a strong objection that a member of a potential coalition can make would be that Horowitz called a multi-threat, i.e., an objection that says that a player can obtain higher payoffs in any alternative coalition. The other potential coalition partner may then be able to make a counter multi-threat, stating that he/she can also do better in any other coalition. The set of outcomes in the competitive bargaining set, then, consists of those payoff configurations where a counter-multi-threat can be raised for any multi-threat. For the example above, the competitive bargaining set specifies outcomes of 54 for player A and 18 for his partner.

The Shapley Value

Shapley (1953) approached n-person games from an entirely different perspective by attempting to make an a priori evaluation of the game for each of the players. To do so Shapley stated three axioms that any value function should have.¹ He then proved that a function satisfying these

axioms existed and that it was unique. The resulting function can be interpreted by assuming that: (1) the coalition of all the players forms in a random order, adding one player at a time; (2) each player receives the marginal payoff which accrues to the coalition when he/she joins; and (3) each of the all-player coalitions is equally likely. The Shapley value for player i , then equals $\sum_j P_j x_{ij}$, where P_j refers to the probability of one order of formation and x_{ij} refers to the marginal payoff assigned to player i in that order. Recently Roth (1977) has shown that for players who are risk neutral, such a value is equivalent to a von Neumann-Morgenstern utility for playing a game.

For the quota game mentioned earlier in this paper, where $v(i) = 0$; $v(AB) = 70$; $v(AC) = 60$; $v(BC) = 50$; $v(ABC) = 75$, the Shapley values for players (A, B, C) are (30, 25, 20).

The Shapley value has been interpreted as a measure of a player's pivotal power in the sense that it assigns a value to each of the players depending on when their presence in a coalition is pivotal. The Shapley value has also been used as the basis for a social psychological model of coalition formation, minimum power theory (Gamson, 1964). An assumption that players will divide the payoffs they receive from particular coalitions in proportion to the pivotal power they contribute to that coalition allows minimum power theory to predict that the winning coalition(s) that require the least total pivotal power will form most frequently. This model will be discussed further with the other social psychological models. It is worth mentioning, however, that minimum power theory is the only model that draws from both game theory and social psychology in formulating predictions.

Social Psychological Models

While the game theoretic models have focused on the different payoffs coalitions can obtain, the social psychological models have focused on the differing amounts of resources that players can bring to coalitions. This emphasis originated with the first social psychological model of coalition behavior (Caplow, 1956) and has allowed the models to predict, in most cases, not only how coalition members will divide the payoff they receive, but also what coalition will form. While this result is an advantage relative to the game theoretic models, the social psychological models are less elegant than those of game theory, and, in particular, rarely consider what the optimal strategies might be in particular coalition situations. This reflects the descriptive philosophy underlying the social psychological models, as against the normative philosophy underlying the game theoretic models.

Caplow's Model

Caplow's (1965) model was the first social psychological theory of coalition formation. Caplow stated that players will attempt to "control" as many other players as possible. In Caplow's terms, all members of a coalition control players outside the coalition, and, within the coalition, the member(s) with the most resources control the other coalition member(s). Resources are important, then, to determine whom one controls within a coalition. (They are also important to determine majority coalitions).

Caplow listed six types of coalitions that differed in the relationship between the players' resources. Two types gave one player dictatorial power; the remaining four types, for player A, B, and C, were: (1) $A = B = C$; (2) $A > B$, $B = C$, $A < (B + C)$; (3) $A > B > C$, $A < (B + C)$; and (4) $A < B$, $B = C$.

The model then made predictions on the basis of each player's attempt to maximize control over the others. For instance, in the second type, above, a BC coalition would give A control over no one, B control over one player, and C control over one. Because this was the best that B could do in the situation, he/she preferred it; because it was the best that C could do in the situation, he/she preferred it. Thus, the model predicts the BC coalition in games of this type. The model does not predict, however, what the payoff distribution will be. In addition, it is restricted to three-person coalition situations.

Caplow (1959) qualified his predictions by stating that control is important only in continuous coalition situations. In episodic situations, where rewards are obtained in periodic, predetermined conditions, control is not as important as sharing in the payoffs. Given an episodic situation, then, Caplow's model predicts that, except for situations where a dictator exists, any coalition should form, and the best prediction for the reward division is an equal split. Caplow (1959) also stated that if the conflict situation is a terminal one, where all the players fight until only one remains, coalitions will only form when two of the players have equal resources; they will coalesce and terminate the existence of the third player, while continuing to exist themselves in what might be called a state of uneasy detente.

Most of the data on coalitions in the triad has been collected on the Type 3 game: the results indicate that the BC coalition is most frequent. Because Caplow's original model predicted either the AC or the BC coalition in this type of game, Chertkoff (1967) proposed a revised version of the model. Chertkoff noted that an assumption of reciprocated choice would allow the Caplow model to make accurate predictions of the BC coalition in type 3 games. Caplow's original analysis stated that in this coalition type,

C is indifferent between either the AC or the BC coalitions (in each he controls one player and is controlled by one). Likewise, player A is indifferent between the AB and the AC coalitions (he controls both players in each). Player B, however, prefers the BC coalition (where he controls two players). Thus, B will always, according to the theory, choose player C as his coalition partner. Chertkoff noted that if one multiplies the proportions of individual choices to determine the probability of reciprocal choices, the BC coalition should occur 50% of the time, the AC coalition should occur 25% of the time, and no reciprocal choices will occur the remaining 25% of the time. If the players are allowed to make new choices when no coalition forms, the BC coalition should result twice as often, overall, as the AC coalition. For the other triad types, this additional assumption results in no change in the model's predictions. This change, as will be discussed below, improves the model's predictions for much of the data that has been reported.

Minimum Resource Theory

Gamson (1961a) proposed his minimum resource theory to predict not only what coalition might be expected to form in a coalition situation, but also what payoffs the members of that coalition might receive. Gamson assumed that the players would attempt to maximize their payoffs (an assumption which is common to almost all coalition theories) and that they would expect their payoffs to be determined by the parity norm, i.e., each player's payoffs would be directly proportional to the resources he contributed to the coalition. For instance, in a coalition situation where players A, B, and C had resources (votes) of 4, 3, and 2, respectively, players B and C would expect to divide the payoff such that B received 60% and C Received 40%. These two assumptions lead to the prediction that the coalition with the least amount of resources necessary to form a majority will form and that the coalition

members will divide the payoff according to the parity norm. Such coalitions will maximize the coalition members' individual rewards because no allotments will be necessary for resources in excess of the minimum necessary. Gamson's minimum resource theory makes predictions identical to Chertkoff's revision of Caplow's models in the six types of triads, and also make predictions for the payoff division. In addition, the theory applies to any n-person ($n \geq 3$) coalition situation where the players are assigned resources.

Gamson's use of an equity-like principle (i.e., the proportion of a player's inputs are expected to be equal to the proportion of his/her outcomes) is also the underlying assumption in minimum power theory (mentioned previously). Instead of using resources as a measure of a person's inputs, minimum power theory uses pivotal power as a measure of one's contributions. Thus, although the two models make quite different predictions in a number of situations, their underlying philosophy is quite similar.

Bargaining Theory

Komorita and Chertkoff's (1973) bargaining theory represents a radical departure from earlier models of coalition formation. Unlike all of the other models which have been discussed, bargaining theory predicts that, for most games, the players' rewards will change over time. (The other models make only static predictions.) The predictions are based on the use of alternative coalitions as threats during the bargaining process. For instance, if players A and C are bargaining over the rewards they will receive from an AC coalition in the 4-3-2 game, both A and C will use the possibility of forming a coalition with B as a threat. Thus, bargaining theory utilizes some of the underlying logic of bargaining set theory. It also utilizes one of the assumptions of minimum resource theory, i.e., that players will use the parity norm in determining their expected rewards.

However, bargaining theory also considers the possibility that the players may also use an "equality norm," i.e., all players divide the payoff equally. In fact, the prediction for the initial trial is that the players will expect their rewards to be midway between the parity and the equality norm's predictions. The coalition which maximizes the player's rewards, given such expectations, is predicted to form. On subsequent trials, the model predicts that the players will use their maximum expectation from alternative coalitions, whether that is determined by the parity norm or the equality norm, as a threat in their negotiations. The predictions for payoff divisions at the asymptotic trial are derived by assuming that each player's reward will be proportional to his/her maximum expectation in alternative coalitions. The model predicts that, as the trials progress, the players will form coalitions that minimize their temptation to defect. This temptation to defect is smallest in the coalition that minimizes the discrepancy between the predicted asymptotic reward and the players maximum expectation from alternative coalitions.

For example, in the 4-3-2 game, the predictions for the initial trial are that the BC coalition will form and will divide the payoff so that B receives 55% and C receives 45% (which is midway between equality, i.e., 50%-50%, and parity, 60%-40%). On the asymptotic trial, however, bargaining theory predicts that the BC coalition will form and that B will receive 50% and C will receive 50%. Both player's maximum expectations in alternative coalitions (i.e., AB and AC) are 50%, as determined by the equality norm. Their threats are equal and, therefore, the theory's predictions are for an equal payoff division. In addition, their predicted payoffs equal their maximum expectations in alternative coalitions, thus reducing their temptation to defect to zero.

Bargaining theory, then, makes differential predictions for the most frequent coalition and its members' payoffs over trials on the basis of the quality of the players' alternatives. It does not, however, specify when the asymptotic trial will occur. It also does not make predictions for situations where maximum expectations cannot be determined, i.e., when resources are not assigned to the players.

The Weighted Probability Model

Komorita (1974) also proposed the weighted probability model to account, at least in part, for the preponderance of coalitions where the number of members was as small as possible. In coalition situations that include more than three players, either two- or three-person coalitions can often attain a majority. Smaller coalitions are expected to occur more frequently than larger coalitions because a large coalition may not only be "more difficult to form but may also be more difficult to maintain" (Komorita, 1974, p. 243). The weighted probability model assumes that individuals will attempt to maximize their rewards, that minimum winning coalitions will form, and that the probability of a coalition's forming is an inverse function of its size:

$$P(C_j) = \frac{w_j}{\sum w_j}$$

where $P(C_j)$ is the probability that coalition j will form, and $w_j = 1/(n_j - 1)$, the weight that indicates the difficulty in forming coalition j as a function of n_j , the number of players included in it. The theory presently assumes that:

$$P_i = \sum_{j \in C_i} P(C_j), \quad i \in C_i,$$

where P_i is the probability that player i will be included in the winning coalition, C_j , and where the summation is over all minimum winning coalitions which include player i . The model then assumes that the player rewards that are proportional to their probability of inclusion (a notion which, like minimum resource and minimum power theories, is an equity-like principle):

$$R_{ij} = \frac{P_i}{\sum_k P_k}, \quad k \in C_j,$$

where R_{ij} equals player i 's expected reward in coalition C_j and where the summation is over all the members of C_j . Finally, in the event that two or more coalitions of equal size present an individual with the same expected reward, the model assumes that he/she will choose the coalition where the players have equal or relatively equal resources.

The model's predictions can be interpreted by noting that resources are instrumental only in determining the minimum winning coalitions; the minimum winning coalition(s) with the fewest number of players should form. Unlike bargaining theory, determination of the players' expected rewards depends on the quantity and size of his/her alternatives rather than the quality of his/her alternatives. A player with twice as many equal-sized alternatives as another player will be predicted to receive a payoff that is twice the size of the other player's.

For instance, in a game where a majority of thirty votes is needed in a winning coalition, and where players (A, B, C, D, E) have (24, 9, 8, 7, 6) votes, player A has three times as many minimum winning alternatives as player B (i.e., AC, AD, and AE versus BCDE) if they are considering an AB coalition. This is also true for a comparison of player A and players C, D, and E. Thus, the model predicts that player A should receive 75% of

of the rewards in a two-person coalition, while his partner should receive 25% of the rewards. In addition, although players B, C, D, and E differ in the amount of resources at their disposal, the number of alternative coalitions they can form is equal and, therefore, predicted payoffs are equal.

The weighted probability model has an advantage over the other social psychological models because: (1) it does not depend on the allotment of resources to the players; and (2) it makes exact predictions for the probabilities of the different coalitions. Its applications are restricted, however, to simple majority games, where the prize to a majority coalition is constant.

Other Models

Two other models will not be seriously discussed because their predictions are even more limited than those of the models that have been presented. One game theoretic model that will not be discussed at length but which considers cooperative, characteristic function games is the Nash bargaining solution (Nash, 1953). The Nash bargaining solution includes that outcome which maximizes the product of the rewards of the players when they all coalesce. For instance, in a game where three players (A, B, C) can receive payoffs (X_A, X_B, X_C) , the Nash bargaining solution is the outcome which maximizes the product $(X_A X_B X_C)$. Because it assumes that all the players will come to an agreement, i.e., that the grand coalition will form, its predictions are somewhat limited; it does not make predictions for coalitions which do not include all the players.

A social psychological model, anticompetitive theory, (Gamson, 1964) makes predictions based almost entirely on the sex of the players. As a result of the data from several studies, Vinacke (1971) has concluded that

females in coalition situations tend to exhibit "accommodative" behavior: they tend to form larger than minimum winning coalitions; they tend to split payoffs equally regardless of their power position; they tend to make proposals which are not in their own interests, etc. Males, on the other hand, have tended to exhibit "exploitative" behavior, showing a strong drive to win and playing very competitively. The anticompetitive model predicts sex differences in coalition behavior, but makes few specific predictions concerning which coalition will form and how the coalition members will apportion the rewards.

Empirical Findings

The empirical findings concerning coalition behavior have rarely considered both game theoretic and social psychological models in the same study. Rather, independent empirical investigations have been undertaken within the two areas. The research, then, will be briefly summarized as it relates to the two areas.

Experiments in Game Theory

Kalisch, Milnor, Nash, and Wering (1954) conducted the first experimental studies in game theory. Their results, however, may have been particular to the individuals in their limited sample (eight people). In addition, most of the games they investigated were played only once. Similar limitations hamper the interpretation of studies by Maschler (Note 2) and Selten and Schuster (1968). Riker's studies (1967; 1971) can also be questioned, because the experimenters discussed the strategies which the players might

have used prior to several of the sessions, resulting in disparate information bases among groups of subjects.

Buckley and Westen have conducted two studies (Buckley and Westen, 1973; Westen and Buckley, 1974) which investigated four- and five-person games with constant payoffs to majority coalitions. Their results indicate that in such games, the most frequent outcomes are majority coalitions which divide the payoff equally. They have also reported (Buckley and Westen, 1976) a slight superiority for the kernel and the bargaining set over von Neumann and Morgenstern's solutions in these games. Lieberman (1971) reports similar findings for three-person games.

Lieberman (1962) presents the results of the first experiment investigating quota games. The three-person zero-sum quota game he studied yielded quotas of 6, 4, and 2 for players A, B, and C. Players were allowed to send messages to one another, and reciprocal agreements were required for the formation of coalitions. The results indicated that coalitions AB and BC were most frequent, and equal divisions of the payoff again predominated. From the subjects' messages and their post-experimental responses, Lieberman observed that the players "would enter into coalitions with the player they trusted, the one they believed would not be tempted to defect from their coalition for a more attractive offer on the next play of the game."

Rapoport and his colleagues have used a computerized procedure in a series of experiments (Horowitz and Rapoport, 1974; Kahan and Rapoport, 1974, 1976; Medlin, 1976; Rapoport and Kahan, 1976). All of the studies have focused on the predictions of the bargaining set (or subset of the bargaining set) for quota games. The basic paradigm consists of the players playing each of several games, randomly rotating their positions in the games. In the three-person games, groups of four players rotate through the positions,

with one player observing each game. Agreements are reached when an offer has been sent, accepted by the recipient, and ratified by the offer's originator.

Four of the five studies investigated the same set of five games (see Table 1). The first study (Kahan and Rapoport, 1974) in the series studied the five games and the effects of public or secret offers. The results indicated that AB coalitions were more frequent than AC or BC coalitions, and that, overall, the players' payoffs were quite close to their quotas, supporting the bargaining set. There were effects due to games, indicating that player A received more than his quota in Games II and III, where the BC coalitions were most frequent. In the other games, BC coalitions were relatively infrequent and player A received somewhat less than a quota payoff.

Two studies in the series (Medlin, 1976; Rapoport and Kahan, 1976) investigated the effects of a range of values taken by the grand coalition for the same five games. The results indicated that the grand coalition formed frequently when it was possible, and that it became more frequent as its payoff increased. One of these two studies (Rapoport and Kahan, 1976) found a difference in games: ABC coalitions were not frequent in Game V. Instead, AB coalitions were again the most frequent in this game. Medlin (1976), however, found no differences in the frequency of the grand coalition over games.

Kahan and Rapoport (1976) found that one-person values affected the formation of coalitions, the payoffs to coalition members, and the bargaining processes. In particular, they found that the results when one-person values were symmetric to the players' quotas were similar to earlier results (Kahan and Rapoport, 1974), when the one-person values were zero. In the

inversely symmetric conditions, however, 'B coalitions were very frequent, even when the grand coalition was possible. Player C, who had a relatively high one-person value, but a low quota, was often content to take his one-person value. Player A, on the other hand, who had a relatively low one-person value but a high quota, was eager to enter a coalition, and tended to receive payoffs that were lower than his quota. Thus, the results in this condition did not support the bargaining set predictions. The authors present what they call a "quota-value model", one that borrows both from the bargaining set and the Shapley value, to explain their results. The model does explain the results in both the symmetric and inversely symmetric conditions better than the other models considered. However, it has not been tested on additional data and will not be considered in depth here.

The fifth study using the North Carolina paradigm (Horowitz and Rapoport, 1974) investigated four- and five-person Apex games (one of which was used as an example earlier in this paper). The study varied: (1) the order for the presentation of offers, with the Apex player either first or last; and (2) the value of the Apex coalition (for half of the groups it was 1.5 times larger than the payoff for the coalition of all the other players). The kernel and the competitive bargaining set models make different predictions in these games, and, thus, this study was able to contrast them empirically. The bargaining set for these games is defined by a range of outcomes from the kernel to the competitive bargaining set.

The results indicated that the Apex coalition occurred in 45 of 48 plays. The Apex player's payoffs were significantly higher when he

made his offers first rather than last. Most importantly, the payoffs to the players were within the bargaining set and were considerably closer to the competitive bargaining set's predictions than to the kernel's.

Two studies of a different nature have recently been completed by Murnighan and Roth (1977, Note 3). These studies investigated the effects of information and communication opportunities on the behavior of a monopolist in three-person and large-group games. Coalitions received a constant payoff of 100 points, and the players stayed in the same position throughout the game. Each study investigated the effects of five conditions that varied whether the payoff division was secret or announced, whether the players' offers, acceptances, and rejections were secret or announced, and whether messages were allowed. (The first study also investigated the effects of announcing the messages, although this had no additional effect).

The results in three-person groups indicated that the monopolists' mean payoffs ranged from 56.5 to 76.7, and that secret payoff divisions and announced offers led to increases in his payoffs over trials and higher overall payoffs than the message conditions. In the second study, where group size ranged from 7 to 12, the monopolists' payoffs ranged from 83.7 to 93.9, and they showed increases over trials in the payoff announced, offers announced, and secret messages conditions. In addition, a significant correlation between group size and the monopolists' payoffs was observed in the messages condition. The two sets of results suggest that communication opportunities and group size interact and affect a monopolist's payoffs. In particular, with small groups (i.e., three-person), communication opportunities seemed to limit the monopolist's payoffs; with larger groups, communication opportunities tended to limit the monopolists' payoffs if the group was not very large (approximately 10 players or more). Further research is needed to test this implication.

The Murnighan and Roth studies also investigated the predictability of several game theoretic and psychological models. The game used in these studies, where one player was a monopolist, resulted in identical predictions for the Weighted Probability Model and Minimum Power Theory. Each model predicts that the monopolist's payoff should be $100 - \frac{100}{n}$, where n = the number of players in the group. The predictions were supported in the three-person groups, and received some support, in the messages conditions, in the large group study.

The data were also compared to Bargaining Theory (Komorita and Chertkoff, 1973) and the game theoretic concept of the core (cf., Luce and Raiffa, 1957). With the assumption that the monopolist's maximum expectation is the entire payoff of 100 points, Bargaining Theory predicts that the monopolist should receive a constant payoff of 75 points regardless of group size or the number of trials played. This prediction is unusual for Bargaining Theory, which normally predicts changes in payoffs over trials. The data from the three-person study support the predictions in two of the six conditions; the large-group study, however, found no support for the model.

The game theoretic concept of the core subsumes the predictions of all of the forms of the Bargaining Set (Aumann and Maschler, 1964). For the two studies, the core solution indicates that the monopolist will receive the entire 100 points. Although this extreme predictions was not strictly supported in either study, the increases in the monopolists' payoffs over trials in the no messages conditions indicates that, in both studies, the bargaining was moving toward the core. In addition, in the large group study, the monopolist received 99 points or more in 64 of the 147 agreements in the no messages groups. Thus, the data

show some support for the core solution.

In summary, results from experiments using characteristic function games generally support the predictions of the bargaining set, although this support has not been universal (e.g., Murnighan and Rown, 1977a). The availability of communication opportunities has limited the payoffs of a player with veto power. Results pertaining to solutions and subsolutions seem to favor subsolutions. And the core, although study on its predictions have been rare, appears to receive support in some situations.

Social Psychological Research

Empirical research on coalition behavior by social psychologists has primarily focused on interactions in triads. Caplow's (1956) early impetus plus the convenience of studying the smallest possible group size have probably contributed to this emphasis. In particular, triads whose resources are distributed so that $A > B > C$ and $A < (B + C)$ have received the most attention. This may be due to Vinacke and Arkoff's (1957) results for the 4-3-2 game. They found that the 3-2 coalition was most frequent and, thus, did not support Caplow's original theory (which predicted either the 4-2 or the 3-2 coalition).

From a game theoretic perspective, the studies on triads are somewhat limited in their generalizability. Triads can produce at most three distinct game types: (1) where each player is equal (but may differ from other players in the number of votes he/she controls); (2) where one player has veto power and must be included in every coalition although he/she cannot win alone; and (3) where one player is a dictator and can win by playing alone. Almost all of the studies on the triad have investigated the first of these three situations; many (cf., Chertkoff, 1970; Stryker, 1972) have found that the two players with the fewest

resources are most likely to form coalitions. Thus the conclusion that "strength is weakness" has been frequent. This conclusion, however, may be an artifact of games where a coalition can be formed by a majority of the players, regardless of the composition of that majority. In three-person games of this type, the player who controls the most resources in these games has conditional power, that is, power only if the other members of the group do not form a coalition. In Vinacke and Arkoff's paradigm, for instance, the player with four votes in the 4-3-2 game will win if the other players do not form a coalition. Vinacke and Arkoff report that no coalition forms approximately 2% of the trials. Thus, it is almost certain that a coalition will form, and that the player with four votes will have no more power than the other players.

The three-person studies, then, generally show that coalitions with the least number of resources will form. Kelley and Arrowood (1960), however, reported that after several trials with each player playing in the same position, coalitions between the two players with the least number of resources are no more frequent than the other coalitions. Thus, even the stability of the "strength is weakness" conclusion is questionable.

Because of the possibility of limited generalizability of the three-person studies, the present paper will focus on research conducted on larger groups ($n \geq 4$). Games with larger groups have particular advantages in that they can investigate both the generalizability of the "strength is weakness" conclusion and more than three patterns of power among the group members.

The first social psychological study of tetrads was conducted by Willis (1962) in an attempt to extend Caplow's (1956) theory for triads. Willis studied two games, where resources were distributed 4-4-3-2 and 5-3-3-2. (It is interesting to note that the player with 2 votes in

the first game was completely superfluous--he could only be a member of non-minimum winning coalitions.) Will's reported that two-person coalitions (4-4 and two 4-3's in the first game and between 5 and any other player in the second game) were equally frequent. Among the three-person coalitions, those predicted by an extended version of Caplow's theory were most frequent. Overall, two-person coalitions were most frequent, tending to support the more recent models. The presentation of the data, however, makes more specific conclusions difficult.

Shears (1966) also studied two games with four players. She found that two person coalitions were more frequent than three-person coalitions in a 4-2-2-1 and 3-1-1-1 game (where player 3 has veto power). In addition, the data for payoff division seem to support the predictions of the Weighted Probability model, compared to Minimum Resource, Minimum Power, and Bargaining theory. However, the data were collected prior to the presentation of the theories, and thus, support for a theory may be confounded with the use of the data in constructing the theory. The two studies do support the conclusion that coalitions will form with the smallest number of players more frequently than larger coalitions. This explicitly supports the Weighted Probability model and implicitly supports Bargaining theory (which also tends to predict the formation of the smallest coalitions).

Chertkoff (1971) investigated the possibility that the formation of small coalitions could have been due to a procedural artifact. Three-person coalitions form in two "steps": in the first step a two-person coalition must form; then, in the second step, a third coalition member is added. Compared to two-person coalitions, which form in one "step," three-person coalitions may be less frequent due to procedural difficulties

rather than to factors inherent in the game or the other manipulations. Chertkoff investigated three games: 80-60-30; 80-(30-30)-30; and 80-30-30-30. Each game was played for one trial. A comparison of the last two games, where a "weak" coalition between two of the 30 players was manipulated, showed that the (30-30)-30 coalition was considerably more frequent than the 30-30-30 coalition, indicating that procedural effects may have influenced the earlier results. The overall results tended to support Bargaining Theory over the other models, while the data from the four-person games tended to support both Bargaining Theory and the Weighted Probability model. Again, however, these data predate the models they support.

Komorita and Meek (Note 1) revised the earlier coalition formation procedures to allow three-person coalitions to form in a single step. Player X could make an offer for an XYZ coalition by sending the same three-person proposal to both Y and Z. If both accepted, the XYZ coalition formed. Thus, a two-person coalition was not a prerequisite for a three-person coalition. Komorita and Meek studied two games: 8-3-3-3 and 8-4-3-2. Players played the same position for several trials and were instructed to obtain as many points as they could. Two-person coalitions were significantly more frequent than three-person coalitions in both games. In addition, the frequencies of the different two-person coalitions in the 8-4-3-2 game were not significantly different from one another. In addition to reinforcing the finding that small coalitions are most frequent, this study suggests that the "strength is weakness" conclusion may not generalize to four-person coalition situations. The data also support Bargaining theory and the Weighted Probability model over other models, again in a pre-theory fashion.

Komorita and Moore (1976) report the first study to test the two recent models after they were proposed. They studied tetrads of males and females in a 10-9-8-3 game, where any three players could form a majority coalition. Thus, this study tested both the predictions of the models and the "strength is weakness" hypothesis. The models predictions are: (1) Minimum Resource theory: 9-8-3 coalition with payoffs of (45-40-15); (2) Bargaining theory: 9-8-3, (36-34-30); and (3) Minimum Power theory and the Weighted Probability model: any coalition, (33-33-33). The results indicated that the 9-8-3 was most frequent, and that the 10-9-8 coalition was fairly frequent for females. The player's outcomes changed over trials: player 10's outcomes decreased over trials while player 3's outcomes increased over trials. All the players' outcomes tended to approach equality as the trials progressed. Thus, Minimum Power theory and the Weighted Probability model received some support for their predictions of the player's outcomes. Minimum Resource theory received support for its prediction of the 9-8-3 coalition, but was not supported with respect to the players' outcomes. Bargaining theory's predictions were supported for both coalition frequencies and the players' outcomes. The results for males supported the theories more than the results for females. Vinacke's notion (1971) of anticompetitiveness in females, then, was supported again by this study.

Murnighan, Komorita, and Szwajkowski (1977) recently completed a study of tetrads in three different games: 8-3-3-3, 8-7-1-1, and 8-7-7-7. The study compared the predictions of the models and manipulated the reference groups of the players to reveal some of the underlying motivations of the players with respect to their instructions. The players' reference groups

were either the players they were bargaining with or players in other groups who were playing in the same position as themselves. The results supported both Bargaining Theory and the Weighted Probability model over Minimum Resource and Minimum Power theories. Bargaining theory made excellent predictions for coalition frequency and payoff division in the 8-3-3-3 and the 8-7-7-7 games; the Weighted Probability model made excellent predictions of the coalition frequencies in each game. The reference group manipulation indicated that there was greater competition and more support for each of the theories when players had reference groups of other similar players. This result reinforces Komorita and Moore's (1976) findings for females: it appears that the theories' predictions receive the most support when the players are competitively motivated. Departures from this condition (due to sex or reference groups) reduces their predictability and generalizability.

Two studies have been conducted on larger groups. Gamson (1961b) investigated five-person groups in three different games. The use of a procedure that separated the formation of a coalition from the division of the payoff among the coalition members limits the applicability of the results.

Vinacke (1971) conducted a study with male and female groups, and varied the number of players for each of five games. Three of the games were inappropriate for differentiating the predictions of the relevant models. The other two were: (1) "All Different", where each player's resources differed (e.g., 5-4-3-2-1); and (2) "One Strong-One Weak", where one player was given one vote, $(n-2)$ players were given 2 votes, and the strong player was given $2(n-2)$ votes. The results neither support nor reject any of the models discussed here. As in the earlier studies, however, sex differences were apparent. Females tended to display accommodative behavior;

males tended to display exploitative behavior. This was particularly evident in the dictatorship and monopolist games: female dictators and female monopolists did not push for higher payoffs. Instead, they often included unnecessary players in the coalitions and demanded relatively low payoffs for themselves.

In summary, the research on coalition behavior in situations with four or more players has typically found that, if two-person coalitions are possible, they will be more frequent than three-person coalitions. In addition the players' outcomes generally support the predictions of Bargaining Theory and the Weighted Probability model. Minimum Resource theory and Minimum Power theory have received relatively little support.

Conclusions and Future Directions

Research and theory on coalition behavior has continued sporadically for thirty years. Due to the inherent difficulties of research on groups, progress has been slow and the results to date lead to more questions than conclusions. The conclusions that can be drawn are almost completely rooted in one of the two basic traditions, game theory and social psychology. Game theory has focused on differences in the payoffs that different coalitions can obtain. Theory has continuously revolved around this variable, and research has found differences in the players' payoffs and (unpredicted) differences in coalition frequencies as a result of differences in coalition payoffs. The ability to obtain high payoffs has been theoretically related to the elusive concept of power (Shapley and Shubik, 1954), and if power is measured by the total payoffs a player obtains during a coalition game, experimental findings support this approach.

Game theoretic research has also found differences in players' payoffs due to the opportunity to communicate with other players. Results also tend to vary, although to a lesser degree, with differences in the amount of information each player has. Thus, the game theoretic literature has successfully pursued the investigation of coalition behavior from the perspective of payoff differences, communication opportunities, and information availability.

Social psychological models, on the other hand, have emphasized differences in resources rather than differences in payoffs. Research has shown that differences in resources affect the frequency of formation of different coalitions and the payoffs that players with different resources obtain. The results, however, are not straightforward. Indeed, conclusions that imply that more resources are an advantage can not be made consistently. Thus, the implications from the social psychological research to the study of power are not clearcut. Resources do have an effect on coalition behavior; the direction and the extent of the effect may interact with the type of game under study.

Social psychological research has also found consistent results pertaining to the sex of the player. Females generally display accommodative behavior: they tend to be cooperative rather than competitive; they pay close attention to the social aspects of bargaining; they tend to be altruistic rather than aggressive. Men, on the other hand, tend to display exploitative behavior, the converse of accommodative behavior. Even in the research reported recently, sex differences have been evident. The generalizability of these results to the entire female population, especially when the predominant subject population has been college undergraduates, requires testing in future research.

One variable that has received some attention in both areas recently has been changes in coalition behavior over time (i.e., the bargaining process). Rapoport and his colleagues have utilized a procedure where the process that results in each agreement can be investigated with respect to the first offer made, the first offer accepted, etc. Social psychologists (e.g., Komorita and Moore, 1976; Murnighan, et al., 1977) have studied games that are played for several trials. The demands of the players, the number of offers each receives, etc., can be analyzed in an attempt to understand the bargaining process that emerges within coalition situations. A series of six trials, then, is not viewed as six independent games; rather, researchers now are considering such a series of trials as a single meta- or super-game. This approach has also been used in recent game theoretic research (e.g., Murnighan and Roth, 1977).

Thus, the paths taken by the bargaining process are being investigated, and evidence about the bases of some of the current models can be observed during these processes. The inherent assumption in Bargaining theory, that players will learn how powerful they are as the trial progress, can be tested. Similarly, the success and failure of justified objections in characteristic function games contributes to tests of the validity of Bargaining Set theory. In addition, observation of the entire process and its results gives greater insight into the possibility that an equilibrium coalition or set of coalitions might result, however tenuous. In this way, the models that make static predictions (e.g., Camson's Minimum Resource Theory, which makes a single prediction, regardless of the number of trials to be played) can be assessed to determine whether the models are supported at particular points (e.g., early or late) during a lengthy bargaining situation. For instance, investigation of the coalition process has indicated that, in some studies, bargaining has moved toward the core (e.g., Murnighan and Roth, Note 3) or toward

the predictions of the Weighted Probability Model (Komorita and Moore, 1976).

In addition to allowing for more precise theoretical tests, investigation of the coalition bargaining process allows for the detection of different levels of skill in bargaining. If the results of coalition studies are even to be compared to the behavior of experienced negotiators, the players must become sophisticated bargainers. Study of the frequencies of different coalitions and the outcomes of different players do not allow a researcher/analyst to determine the skill level of the players. Although the results may be the same (or nearly the same) for sophisticated and unsophisticated bargainers, the process that contributes to the formation of coalitions for the two sets of players can be markedly different.

Another variable that has received some attention by the two areas has been the differences in games. Rapoport and his colleagues have completed a systematic study of five different games, and have found some consistent differences between the games. The research of social psychologists have typically included more than a single game. The selection of games, however, has been relatively unsystematic since Vinacke and Arkoiff's (1957) initial study.

With little exception, then, research on coalition behavior has suffered from both the absence of systematic study of the potential variables that may affect the players' behavior and the relatively uncoordinated thrusts in the two areas. Several directions for future research stand out clearly. Research and theory that investigates both differential payoffs for the possible coalitions and differential resource distributions among the players would be a major contribution. Both variables have had considerable effects on coalition behavior when they have been studied independently. Research that studies them together may indicate which variable contributes

most to the behavior of coalition bargainers, and which theoretical approach best predicts that behavior. The outcomes and strategies used by players with many resources and a relative inability to obtain high coalition payoffs, for instance, can be compared to players with low resources and the ability to obtain high payoffs.

In addition, study of the two variables simultaneously may yield results that more closely approximate coalition behavior in the "real world." Coalition situations for politicians, corporations, or family members often include players with different resources and coalitions that can obtain different payoffs. Thus, a concerted effort that bridges game theoretic and social psychological approaches to coalition formation holds promise not only for richer theory but also for more generalizable results.

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TABLE 1

Five Characteristic Function Games Used in the North Carolina Studies

Game	<u>Value of Coalitions</u>			<u>Quotas</u>		
	<u>$v(AB)$</u>	<u>$v(AC)$</u>	<u>$v(BC)$</u>	w_A	w_B	w_C
I	95	90	65	60	35	30
II	115	90	85	60	55	30
III	95	88	81	51	44	37
IV	106	86	66	63	43	23
V	118	84	50	76	42	8



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